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Evans

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(54) **SWITCHING ROLLER FINGER FOLLOWER WITH END STOPS IN SECONDARY ARMS**

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F01L 1/34 (2006.01)
F01L 1/18 (2006.01)

(52) **U.S. Cl.**
CPC ***F01L 1/18*** (2013.01); *Y10T 29/49556* (2015.01); *Y10T 74/2107* (2015.01)

(58) **Field of Classification Search**
CPC F01L 1/18; F16H 25/14
USPC 123/90.16, 90.39
See application file for complete search history.

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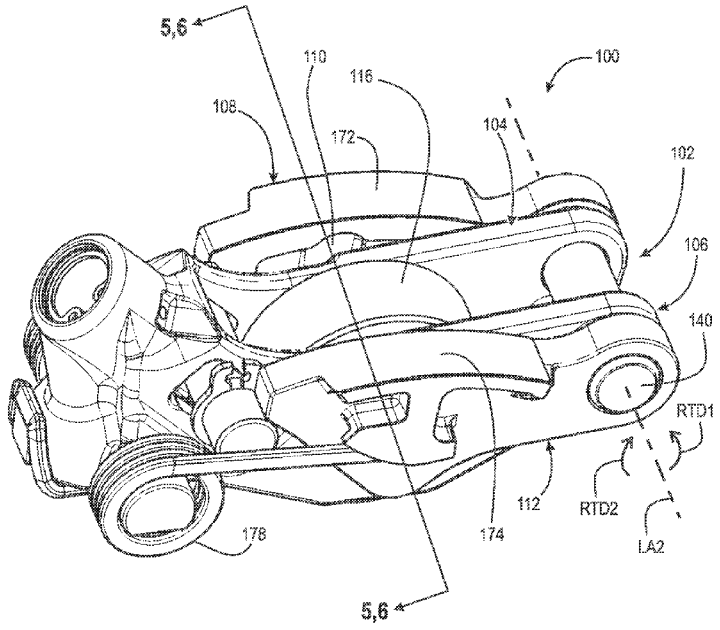
(57) **ABSTRACT**

A switching roller finger follower including: a housing including first and second walls; a first secondary arm pivotably connected to the housing and including a first groove; a second secondary arm pivotably connected to the housing and including a second groove; and a roller disposed between the first and second walls and including an axle passing through the walls and having a first end disposed in the first groove and a second end disposed in the second groove. A method of fabricating a switching roller finger follower, including: disposing a roller between first and second walls for a housing; passing an axle through the roller and the walls; pivotably connecting first and second secondary arms to the housing; disposing a first end of the axle in a first groove in the first arm; and disposing a second end of the axle in a second groove in the second arm.

19 Claims, 10 Drawing Sheets



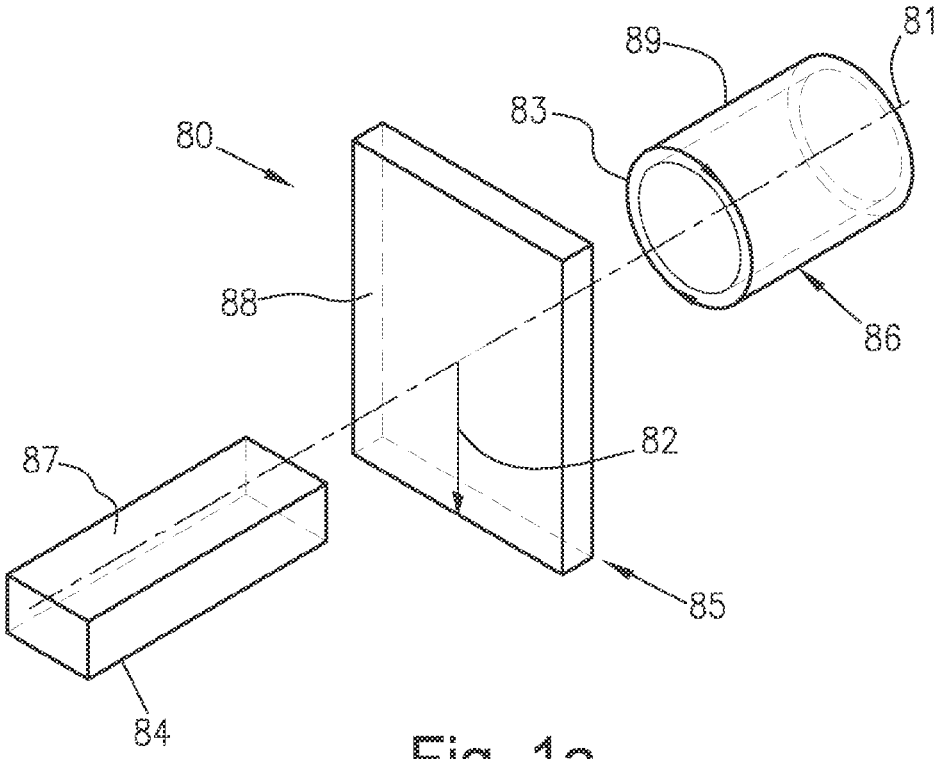


Fig. 1a

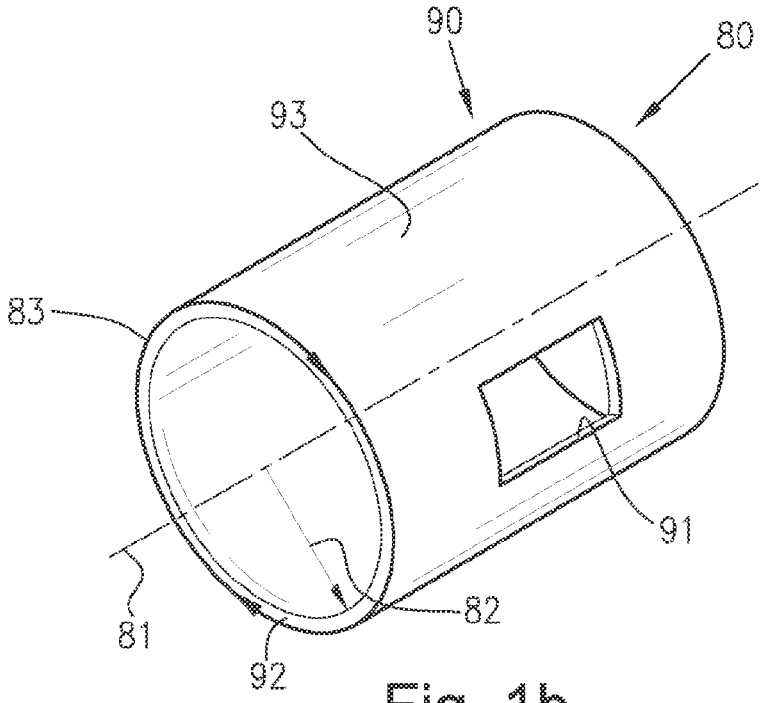


Fig. 1b

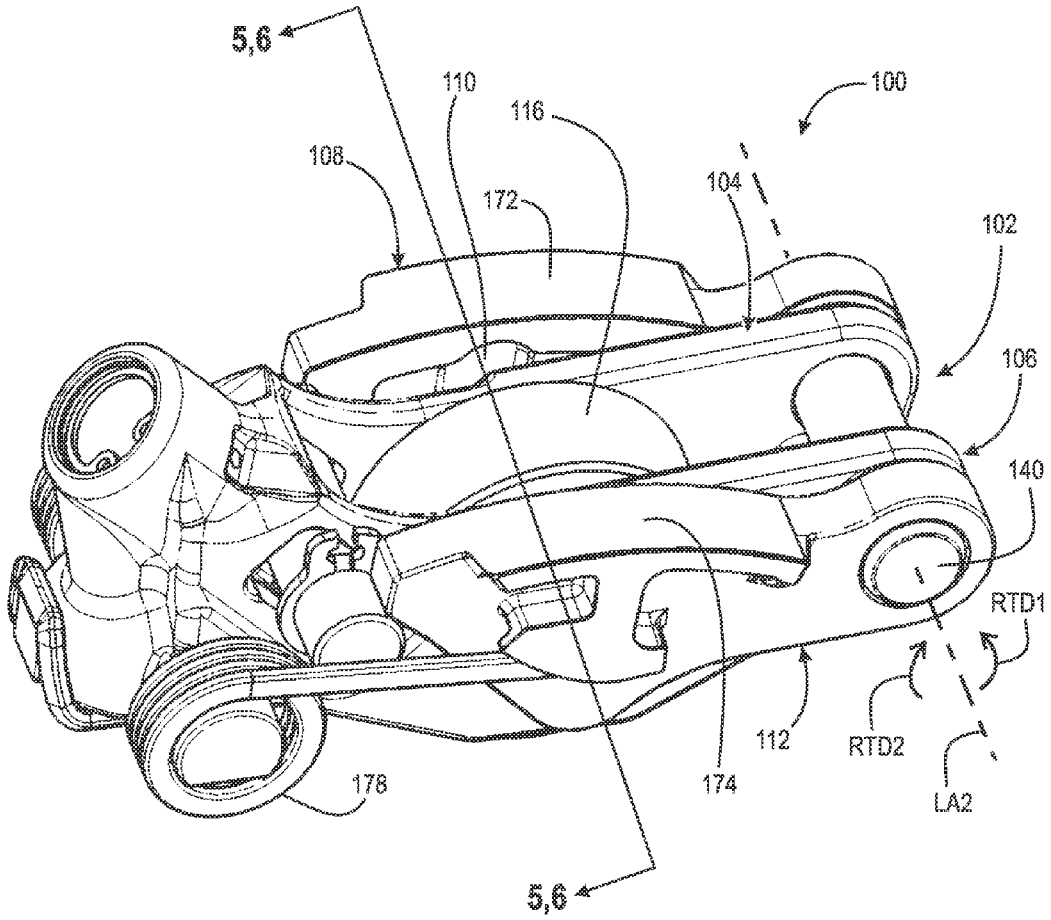

5,6
110
116
100
108
172
104
102
106
140
RTD1
112
RTD2
LA2
178
174
5,6

Fig. 2

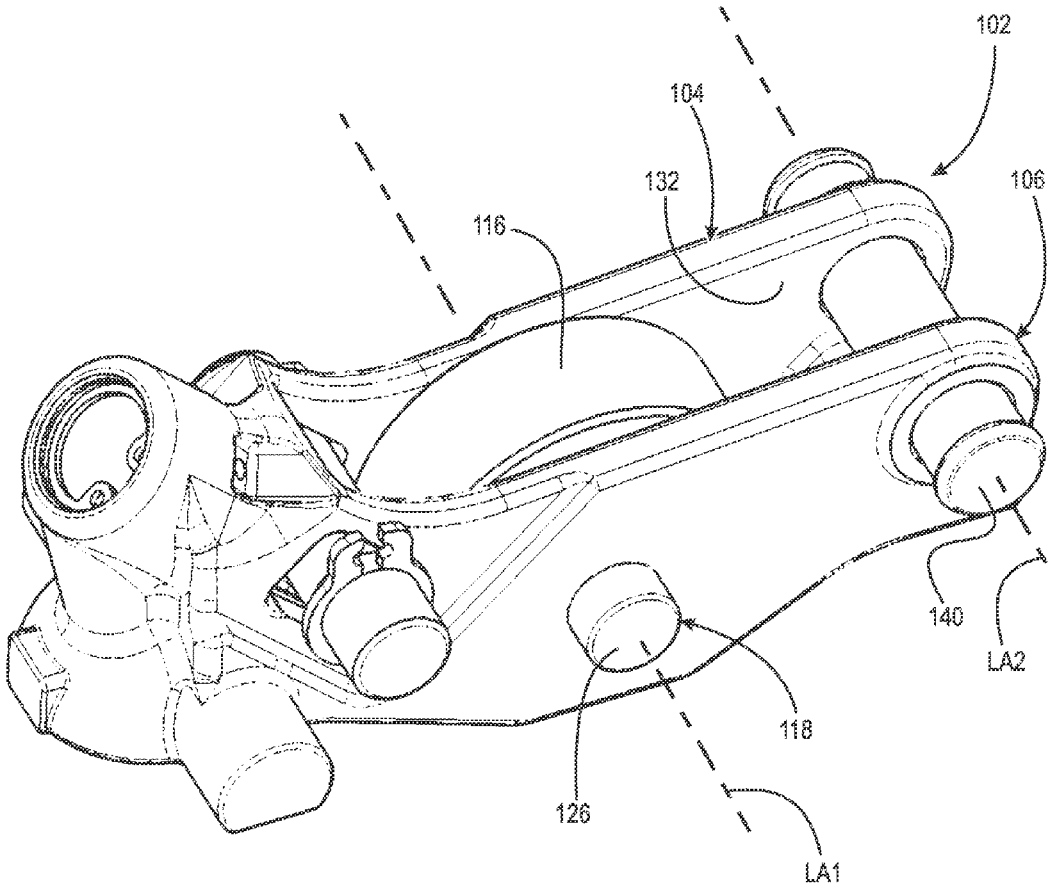


Fig. 3

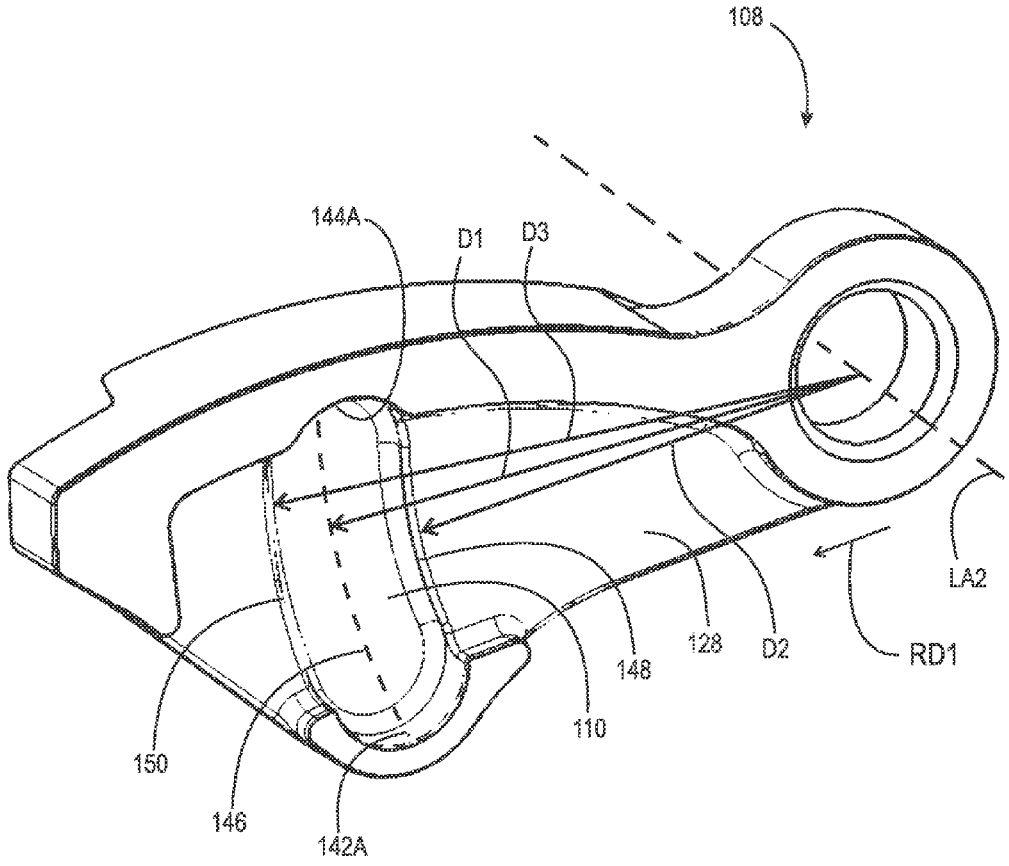


Fig. 4

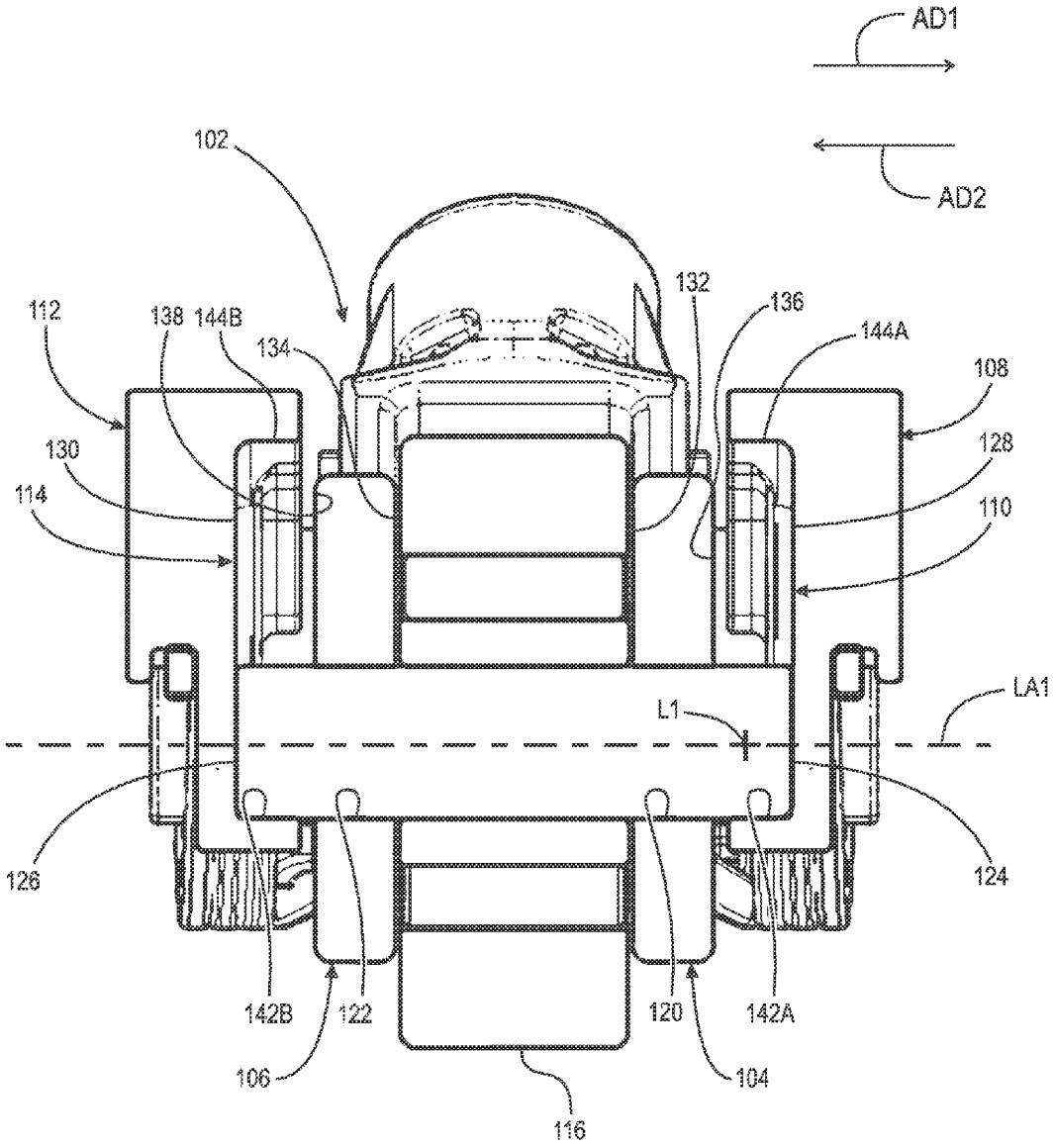

AD1
AD2
102
112
138
144B
134
132
136
144A
108
130
128
114
110
LA1
L1
126
124
142B
122
120
142A
106
104
116

Fig. 5

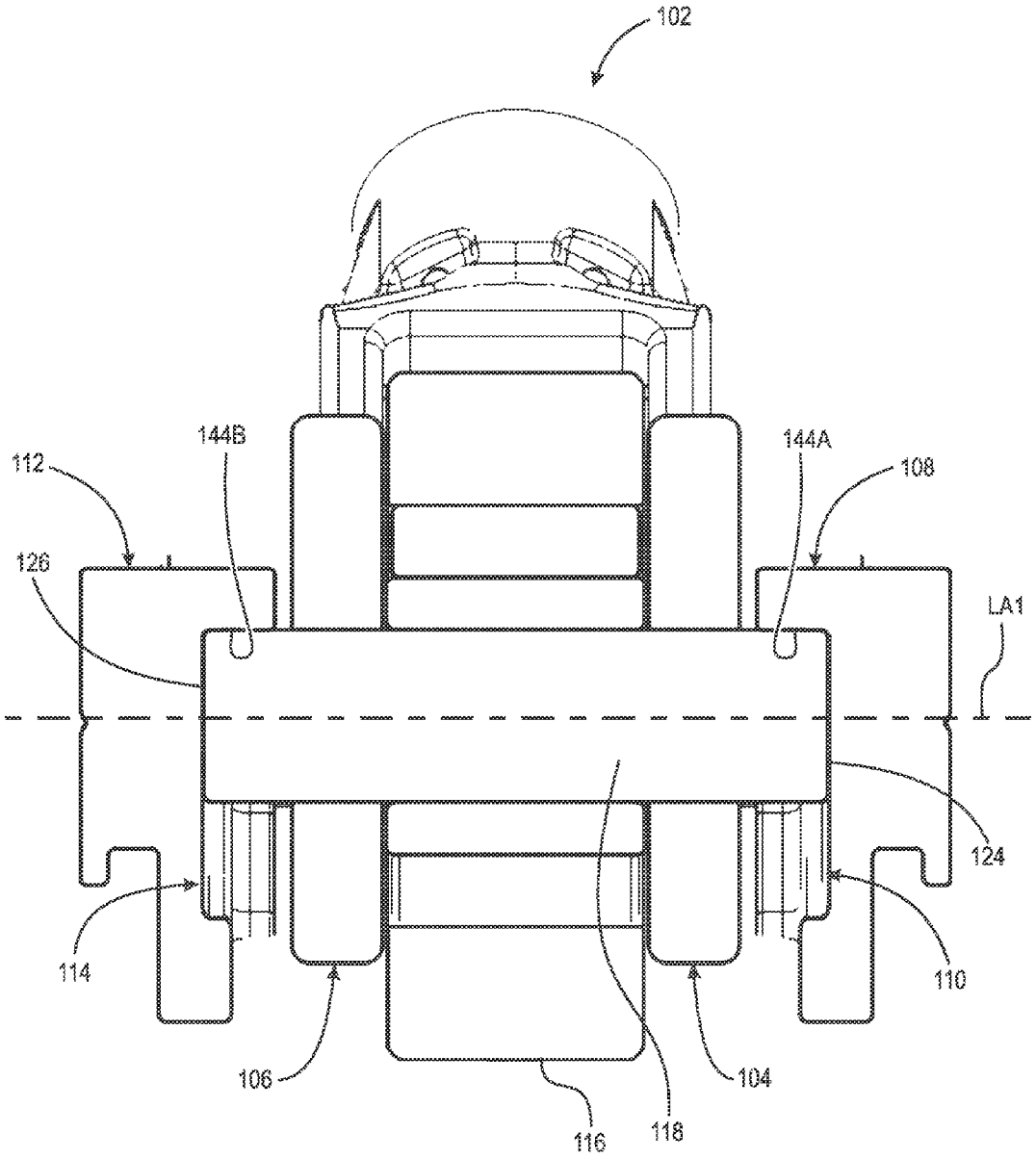


Fig. 6

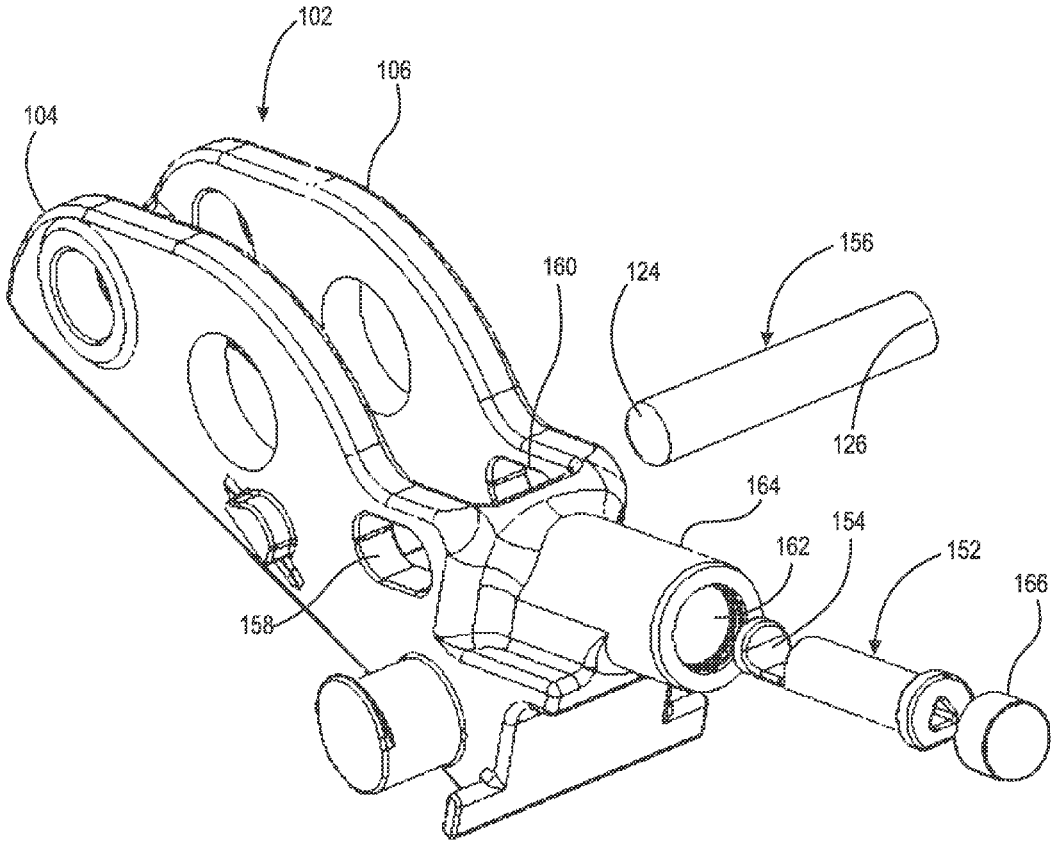


Fig. 7

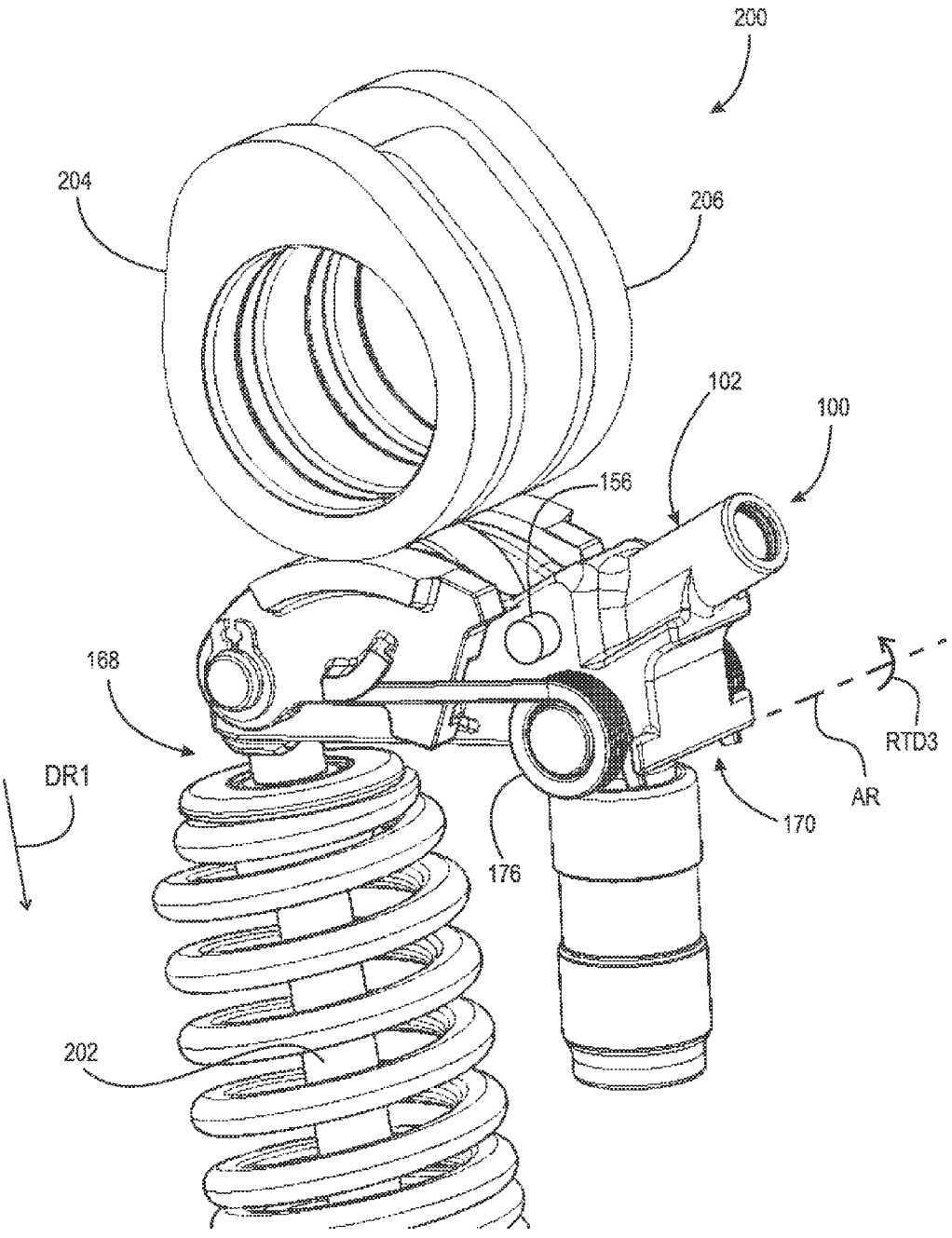


Fig. 8

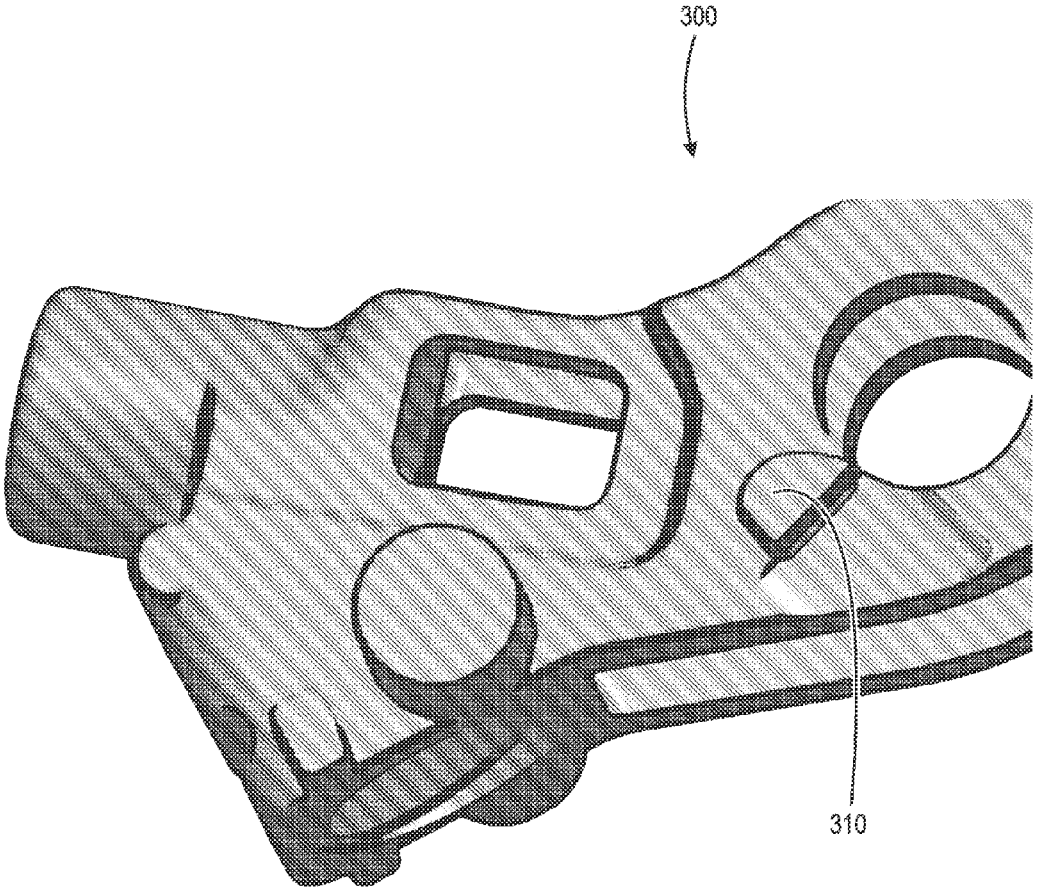


Fig. 9

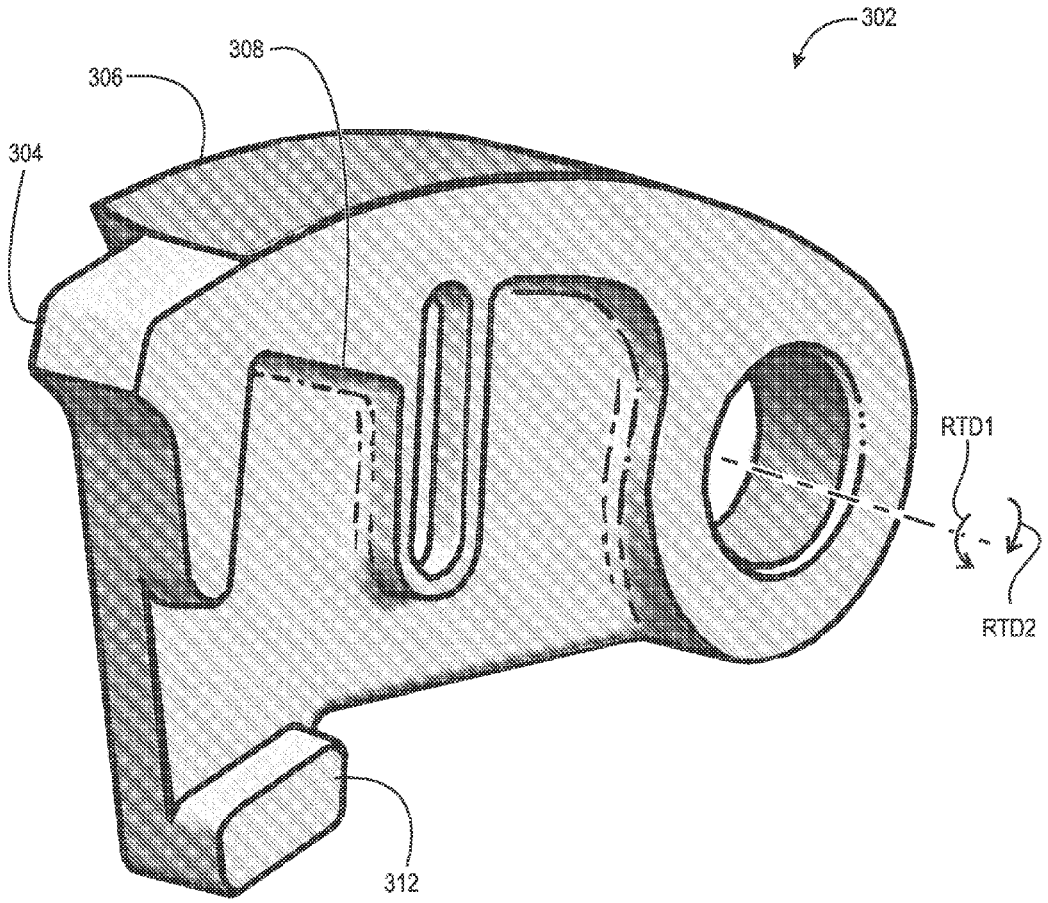


Fig. 10

SWITCHING ROLLER FINGER FOLLOWER WITH END STOPS IN SECONDARY ARMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119 (e) of U.S. Provisional Patent Application No. 61/905,527, filed Nov. 18, 2013, which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to a switching roller finger follower with secondary arms having ends stops formed by grooves in the secondary arms. Respective ends of an axle for a roller bearing in the switching roller finger follower are configured to engage the ends stops to limit rotation of the secondary arms.

BACKGROUND

FIG. **9** is a perspective view of a protrusion, on housing **300** of a prior art switching roller finger follower, for engaging ends stops on a secondary arm.

FIG. **10** is a perspective view of end stops on prior art secondary arm **302**. The following should be viewed in light of FIGS. **9** and **10**. Transport and overswing ends stops are used in switching roller finger followers to prevent excessive rotation of secondary arms, which can cause damage to the follower, as a result of malfunction of the follower.

For example, as is known in the art, a locking pin (not shown) is used to block rotation of the secondary arms during a locked mode. For example, end **304** of arm **302** is arranged to contact the locking pin when force from a cam lobe (not shown) engaged with surface **306** of arm **302** causes arm **302** to rotate in direction RTD**1**. If the locking pin does not displace the proper distance at the proper time (a mis-switch), the force from the cam lobe causes end **304** to slide past the locking pin so that arm **302** continues to rotate in direction RTD**1**. Overswing endstop **308**, formed in arm **302**, is configured to engage protrusion **310** on housing **300** to block further rotation in direction RTD**1**. However, a large rotational force is imparted to arm **302** by the cam lobe and the magnitude of this force can cause endstop **308** to shear protrusion **310** from housing **300** causing further rotation of arm **302**. This further rotation can cause failure of a follower including housing **300** and arm **302**. For example, a lost motion spring (not shown) engaged with arm **302** is used to urge arm **302** in direction RTD**2**, opposite RTD**1**, as described below. If arm **302** is rotated too far in direction RTD**1**, the spring is overstressed, resulting in various failure modes for a switching roller finger follower including housing **300** and arm **302**.

After a mis-switch in the locked mode, the locking pin retracts to enable rotation of the secondary arm in direction RTD**2** via a spring (not shown). Rotation of the secondary arm in direction RTD**2** is blocked by contact of transport endstop **312**, formed in secondary arm **302**, with protrusion **310**. The rotation of the secondary arm in direction RTD**1** is opposed by the spring force of the spring. The additional rotation of the secondary arm due to the mis-switch results in an increase in the spring force, which further results in an increase of the force applied by endstop **312** to protrusion **310**. The magnitude of this force can cause endstop **308** to shear protrusion **310** from housing **300** enabling excess rotation of arm **302** in direction RTD**2**, which can cause failure of a follower including housing **300** and arm **302**.

SUMMARY

According to aspects illustrated herein, there is provided a switching roller finger follower, including: a housing including first and second walls; a first secondary arm pivotably connected to the housing and including a first groove; a second secondary arm pivotably connected to the housing and including a second groove; and a roller disposed between the first and second walls and including a first axle passing through the first and second walls and having a first end disposed in the first groove and a second end disposed in the second groove.

According to aspects illustrated herein, there is provided a switching roller finger follower, including: a housing including first and second walls; a first secondary arm pivotably connected to the housing and including a first groove with first and second ends; a second secondary arm pivotably connected to the housing and including a second groove with third and fourth ends; and a roller disposed between the first and second walls and including a first axle passing through the first and second walls and having a first end disposed in the first groove and a second end disposed in the second groove. The first and third ends block pivoting of the first and second secondary arms in a first direction. The second and fourth ends block pivoting of the first and second secondary arms in a second direction opposite the first direction.

According to aspects illustrated herein, there is provided a method of fabricating a switching roller finger follower, including: disposing a roller between first and second walls for a housing; passing a first axle through the roller and through first and second through-bores in the first and second walls, respectively; pivotably connecting first and second secondary arms to the housing; disposing a first end of the first axle in a first groove in the first secondary arm; and disposing a second end of the first axle in a second groove in the second secondary arm.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments are disclosed, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, in which:

FIG. **1**A is a perspective view of a cylindrical coordinate system demonstrating spatial terminology used in the present application;

FIG. **1**B is a perspective view of an object in the cylindrical coordinate system of FIG. **2**A demonstrating spatial terminology used in the present application;

FIG. **2** is a perspective view of a switching roller finger follower with ends stops in secondary arms;

FIG. **3** is perspective view of the switching roller finger follower in FIG. **2** with the secondary arms removed;

FIG. **4** is a perspective view of a secondary arm from FIG. **2** showing a groove;

FIG. **5** is a cross-sectional view generally along line **5**/**6**-**5**/**6** in FIG. **2** with the secondary arms contacting transport end stops;

FIG. **6** is a cross-sectional view generally along line **5**/**6**-**5**/**6** in FIG. **2** with the secondary arms contacting overswing end stops;

FIG. **7** is an exploded view of the switching roller finger follower in FIG. **2** with the secondary arms and roller removed;

FIG. **8** is a perspective view of the switching roller finger follower of FIG. **2** in an unlocked mode and engaged with a valve train;

FIG. **9** is a perspective view of a protrusion on a housing of a prior art switching roller finger follower for engaging with ends stops on a secondary arm; and,

FIG. **10** is a perspective view of end stops on a prior art secondary arm.

DETAILED DESCRIPTION

At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements of the disclosure. It is to be understood that the disclosure as claimed is not limited to the disclosed aspects.

Furthermore, it is understood that this disclosure is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present disclosure.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. It should be understood that any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the disclosure.

FIG. **1**A is a perspective view of cylindrical coordinate system **80** demonstrating spatial terminology used in the present application. The present invention is at least partially described within the context of a cylindrical coordinate system. System **80** has a longitudinal axis **81**, used as the reference for the directional and spatial terms that follow. The adjectives "axial," "radial," and "circumferential" are with respect to an orientation parallel to axis **81**, radius **82** (which is orthogonal to axis **81**), and circumference **83**, respectively. The adjectives "axial," "radial" and "circumferential" also are regarding orientation parallel to respective planes. To clarify the disposition of the various planes, objects **84**, **85**, and **86** are used. Surface **87** of object **84** forms an axial plane. That is, axis **81** forms a line along the surface. Surface **88** of object **85** forms a radial plane. That is, radius **82** forms a line along the surface. Surface **89** of object **86** forms a circumferential plane. That is, circumference **83** forms a line along the surface. As a further example, axial movement or disposition is parallel to axis **81**, radial movement or disposition is parallel to radius **82**, and circumferential movement or disposition is parallel to circumference **83**. Rotation is with respect to axis **81**.

The adverbs "axially," "radially," and "circumferentially" are with respect to an orientation parallel to axis **81**, radius **82**, or circumference **83**, respectively. The adverbs "axially," "radially," and "circumferentially" also are regarding orientation parallel to respective planes.

FIG. **1**B is a perspective view of object **90** in cylindrical coordinate system **80** of FIG. **1**A demonstrating spatial terminology used in the present application. Cylindrical object **90** is representative of a cylindrical object in a cylindrical coordinate system and is not intended to limit the present invention in any manner. Object **90** includes axial surface **91**, radial surface **92**, and circumferential surface **93**. Surface **91** is part of an axial plane, surface **92** is part of a radial plane, and surface **93** is a circumferential surface.

FIG. **2** is a perspective view of switching roller finger follower **100** with ends stops in secondary arms.

FIG. **3** is perspective view of switching roller finger follower **100** in FIG. **2** with secondary arms removed.

FIG. **4** is a perspective view of a secondary arm from FIG. **2** showing a groove.

FIG. **5** is a cross-sectional view generally along line **5**/**6**-**5**/**6** in FIG. **2** with the secondary arms contacting transport end stops.

FIG. **6** is a cross-sectional view generally along line **5**/**6**-**5**/**6** in FIG. **2** with the secondary arms contacting overswing end stops. The following should be viewed in light of FIGS. **2** through **6**. Switching roller finger follower **100** includes: housing **102** with walls **104** and **106**; secondary arm **108** pivotably connected to the housing and including groove **110**; secondary arm **112** pivotably connected to the housing and including groove **114**; and roller **116**. Roller **116** is disposed between the walls **104** and **106** and includes axle **118** passing through walls **104** and **106**, in particular through through-bores **120** and **122** in walls **104** and **106**, respectively. Axle **118** includes end **124** disposed in groove **110** and end **126** disposed in groove **114**. As further described below, contact between ends **124** and **126** and secondary arms **108** and **112**, respectively, is arranged to limit an extent of rotation of secondary arms **108** and **112** with respect to housing **102**.

In an example embodiment, grooves **110** and **114** are formed as indentations in surfaces **128** and **130** of arms **108** and **112**, respectively, that is, the grooves do not pass completely through material forming the secondary arms. In an example embodiment (not shown), grooves **110** and **114** pass completely through material forming the secondary arms.

Walls **104** and **106** includes walls surfaces **132** and **134**, respectively, facing each other and roller **116** is disposed between surfaces **132** and **134**. Axle **118** includes longitudinal axis LA**1**, wall **104** includes surface **136** facing in axial direction AD**1** parallel to longitudinal axis LA**1**, and wall **106** includes surface **138** facing in axial direction AD**2**, opposite AD**1**. End **124** of axle **118** extends past surface **136** in direction AD**1** and end **126** of axle **118** extends past surface **138** in direction AD**2**.

Switching roller finger follower **100** includes axle **140**, with longitudinal axis LA**2**, passing through walls **104** and **106**. Secondary arms **108** and **112** are engaged with axle **140** as is known in the art and are pivotable about axle **140**. Groove **110** is bounded by transport stop end **142**A and overswing stop end **144**A. Groove **114** is bounded by transport stop end **142**B and overswing stop end **144**B. Rotation of secondary arms **108** and **112** about axle **140** is blocked in rotational direction RTD**1** by contact of ends **124** and **126** with ends **144**A and **144**B. Rotation of secondary arms **108** and **112** about axle **140** is blocked in rotational direction RTD**2**, opposite direction RTD**1**, by contact of ends **124** and **126** with ends **142**A and **144**B. Center line **146** connects ends **142**A and **144**A at fixed distance D**1** from longitudinal axis LA**2**, in direction RD**1** orthogonal to axis LA**2**. The discussion regarding centerline **146** is applicable to groove **114**.

Groove **110** is bounded by side walls **148** and **150** at fixed distances D**2** and D**3**, respectfully, from axis LA**2** in a direction RD**1**. Line L**1** orthogonal to axis LA**2** passes through axle **118** and side walls **148** and **150**. The discussion regarding side walls **148** and **150** is applicable to groove **114**.

FIG. **7** is an exploded view of switching roller finger follower **100** in FIG. **2** with the secondary arms and roller removed. The following should be viewed in light of FIGS. **2** through **7**. Switching roller finger follower **100** includes shuttle pin **152** with notch **154** and locking pin **156** passing through the notch. Locking pin **156** passes through slots **158** and **160** in walls **104** and **106**, respectively. Shuttle pin is at least partially disposed in passageway **162** in locking barrel **164**. Seal **166** seals passageway **162**. As is known in the art, in a locked mode for switching roller finger follower **100**, locking pin **156** is positioned to block rotation of secondary arms **108** and **112** about axle **140**.

FIG. **8** is a perspective view of switching roller finger follower **100** of FIG. **2** in an unlocked mode and engaged with valve train **200**. The following should be viewed in light of FIGS. **2** through **8**. Follower **100** includes contact surface **168** and attachment portion **170** arranged to pivotably connect the housing **102** to a support element. The contact surface is arranged to contact valve stem **202**. In the locked mode, cam lobes **204** and **206** of a cam shaft (not shown) for valve train **200**, including valve stem **202**, are arranged to contact arms **108** and **112**, in particular contact surfaces **172** and **174**, respectively. Since rotation of arms **108** and **112** is blocked by contact with locking pin **156**, the pressure applied by the cam lobes causes the follower to pivot around axis AR for the connection point in direction RTD**3**. Via contact surface **166**, follower **100** pushes the stem in direction DR1, for example, to open a valve including the valve stem.

In the unlocked mode, when the cam lobes contact secondary arms **108** and **112**, the arms are free to pivot about axle **140**, for example, in direction RTD**1**. Thus, the contact between the cam lobes and secondary arms **108** and **112** is accommodated by the pivoting such that contact between the cam lobes and secondary arms **108** and **112** does not cause housing **102** to displace with respect to the support element. Therefore, the cam lobes do not cause follower **100** to operate the valve. Springs **176** and **178** urge arms **108** and **112**, respectively, in direction RTD**2** to ensure that arms **108** and **112** are in position for the locking mode.

As noted above, excessive rotation of arms **108** and **112** can cause malfunctioning of follower **100**. For example, in a mis-switch of follower **100**, endstops **142**A/B and **144**A/B contact ends **124** and **126** with significant force. Advantageously, axle **118** is extremely robust and provides the desired rotational blockage of arms **108** and **112** without incurring damage. Thus, the use of ends **124** and **126** to engage endstops **142**A/B and **144**A/B ensures that in the event of malfunction of follower **100**, for example, due to a mis-switch, rotation of arms **108** and **112** is limited in a manner enabling follower **100** to recover from the malfunction.

It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

The invention claimed is:

1. A switching roller finger follower, comprising:
- a housing including first and second walls;
- a first secondary arm pivotably connected to the housing and including a first groove;
- a second secondary arm pivotably connected to the housing and including a second groove;
- a roller:
  - disposed between the first and second walls; and,
  - including a first axle passing through the first and second walls and having:
    - a first end disposed in the first groove; and,
    - a second end disposed in the second groove; and,
- a second axle passing through the first and second walls, wherein the first and second secondary arms are pivotable about the second axle.

2. The switching roller finger follower of claim **1**, wherein contact between the first and second ends and the first and second secondary arms is arranged to limit an extent of rotation of the first and second secondary arms with respect to the housing.

3. The switching roller finger follower of claim **1**, wherein:
- the first groove is bounded by third and fourth ends in the first secondary arm;
- the second groove is bounded fifth and sixth ends in the second secondary arm; and,
- rotation of the first and second secondary arms about the second axle is blocked:
  - in a first direction by contact of the first and second ends of the first axle with the third and fifth ends; and,
  - in a second direction, opposite the first direction, by contact of the first and second ends of the first axle with the fourth and sixth ends.

4. The switching roller finger follower of claim **3**, wherein a first center line connecting the respective third and fourth ends of the first groove is at a fixed distance, from the longitudinal axis for the second axle, in a direction orthogonal to the longitudinal axis for the second axle.

5. The switching roller finger follower of claim **1**, wherein:
- the first and second walls include first and second surfaces, respectively facing each other; and,
- the roller is disposed between the first and second surfaces.

6. The switching roller finger follower of claim **1**, wherein:
- the first axle includes a longitudinal axis;
- the first wall includes a first surface facing in a first axial direction parallel to the longitudinal axis;
- the second wall includes a second surface facing away from the first surface in a second axial direction, opposite the first axial direction;
- the first end of the axle extends past the first surface in the first axial direction; and,
- the second end of the axle extends past the second surface in the second axial direction.

7. The switching roller finger follower of claim **1**, wherein:
- the first axle includes a longitudinal axis;
- the first groove is bounded by first and second side walls at first and second fixed distances, respectfully, from the longitudinal axis in a direction orthogonal to the longitudinal axis;
- the second groove is bounded by third and fourth side walls at the first and second fixed distances, respectfully, from the longitudinal axis in the direction orthogonal to the longitudinal axis;
- a first line orthogonal to the longitudinal axis passes through the first axle and the first and second side walls; and,
- a second line orthogonal to the longitudinal axis passes through the first axle and the third and fourth side walls.

8. The switching roller finger follower of claim 1 further comprising:
a locking pin passing through first and second slots the first and second walls, respectively; and,
a shuttle pin including a notch, wherein:
the housing includes a locking barrel with a passageway;
the shuttle pin is at least partially disposed in the passageway;
the locking pin passes through the notch; and,
in a locked mode, the locking pin is positioned to block rotation of the first and second secondary arms.

9. A switching roller finger follower, comprising:
a housing including first and second walls;
a first secondary arm pivotably connected to the housing and including a first groove with first and second ends;
a second secondary arm pivotably connected to the housing and including a second groove with third and fourth ends; and,
a roller:
disposed between the first and second walls; and,
including a first axle passing through the first and second walls and having:
a first end disposed in the first groove; and,
a second end disposed in the second groove, wherein:
the first and third ends block pivoting of the first and second secondary arms in a first direction; and,
the second and fourth ends block pivoting of the first and second secondary arms in a second direction opposite the first direction.

10. The switching roller finger follower of claim 9, further comprising:
a second axle passing through the first and second walls, wherein:
the first and second secondary arms are engaged with the second axle and are pivotable about the second axle;
the first groove is bounded by third and fourth ends in the first secondary arm;
the second groove is bounded fifth and sixth ends in the second secondary arm; and,
rotation of the first and second secondary arms about the second axle is blocked:
in a first direction by contact of the first and second ends of the first axle with the third and fifth ends; and,
in a second direction, opposite the first direction, by contact of the first and second ends of the first axle with the fourth and sixth ends.

11. The switching roller finger follower of claim 9, wherein:
the first axle includes a longitudinal axis;
the first wall includes a first surfaces facing in a first axial direction parallel to the longitudinal axis;
the second wall includes a second surfaces facing away from the first surface in a second axial direction, opposite the first axial direction;
the first end of the axle extends past the first surface in the first axial direction; and,
the second end of the axle extends past the second surface in the second axial direction.

12. The switching roller finger follower of claim 9 further comprising:
a locking pin passing through first and second slots the first and second walls, respectively; and,
a shuttle pin including a notch, wherein:
the housing includes a locking barrel with a passageway;
the shuttle pin at least partially disposed in the passageway;
the locking pin passes through the notch; and,
in a locked mode, the locking pin is positioned to block rotation of the first and second secondary arms.

13. A method of fabricating a roller finger follower, comprising:
disposing a roller between first and second walls for a housing;
passing a first axle through the roller and through first and second through-bores in the first and second walls, respectively;
passing a second axle through the first and second walls;
pivotably connecting first and second secondary arms to the second axle;
disposing a first end of the first axle in a first groove in the first secondary arm; and,
disposing a second end of the first axle in a second groove in the second secondary arm.

14. The switching roller finger follower of claim 13, wherein:
in the locked mode:
the first and second outer arms are arranged to contact first and second cam lobes from a plurality of cam lobes; and,
the first and second outer arms are arranged to contact the locking pin to block rotation of the first and second secondary arms; and,
in the unlocked mode:
the first and second outer arms are arranged to contact the first and second cam lobes, respectively; and,
the first and second outer arms are arranged to pivot with respect to the housing during contact with the first and second cam lobes.

15. The method of claim 13, wherein:
contact between the first and second secondary arms and the first and second ends of the first axle, respectively, is arranged to limit pivoting of the first and second secondary arms, respectively.

16. The method of claim 13, wherein:
the first and second walls include first and second surfaces, respectively facing each other; and,
disposing the roller between the first and second walls includes disposing the roller between the first and second surfaces.

17. The method of claim 13, wherein:
the first axle includes a longitudinal axis;
the first wall includes a first surfaces facing in a first axial direction parallel to the longitudinal axis;
the second wall includes a second surfaces facing away from the first surface in a second axial direction, opposite the first axial direction; and,
passing the first axle through the first and second through-bores includes:
extending the first end of the axle past the first surface in the first axial direction; and,
extending the second end of the axle past the second surface in the second axial direction.

18. The method of claim 13,
wherein:
the first axle includes a longitudinal axis;
the first groove is bounded by first and second side walls at first and second fixed distances, respectfully, from the longitudinal axis in a direction orthogonal to the longitudinal axis;

the second groove is bounded by third and fourth side walls at the first and second fixed distances, respectfully, from the longitudinal axis in the direction orthogonal to the longitudinal axis;

disposing a first end of the first axle in the first groove includes disposing the first end such that a first line orthogonal to the longitudinal axis passes through the first axle and the first and second side walls; and,

disposing the second end of the first axle in the second groove includes disposing the second end such that a second line orthogonal to the longitudinal axis passes through the first axle and the third and fourth side walls.

19. The method of claim **13**, further comprising:

passing a locking pin through first and second slots in the first and second walls, respectively;

placing a shuttle pin in a passageway in a locking barrel for the housing; and,

passing the locking pin through a notch in the shuttle pin, wherein the locking pin is displaceable such that in a locked mode, the locking pin blocks rotation of the first and second secondary arms.

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